DOCUMENT RESUME

ED 431 733 SP 038 594

AUTHOR Segal, Gilda
TITLE Collisions in a Science Education Reform Context: Anxieties, Roles and Power.
PUB DATE 1999-04-21
NOTE 27p.; Paper presented at the Annual Meeting of the American Educational Research Association (Montreal, Quebec, Canada, April 19-23, 1999).
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Anxiety; *Educational Change; Educational Improvement; Elementary Education; *Elementary School Science; Elementary School Teachers; Foreign Countries; Higher Education; Preservice Teacher Education; *Science Education; *Self Evaluation (Individuals); Student Teacher Attitudes; Student Teachers; Teacher Collaboration; Teacher Researchers; Teacher Student Relationship
IDENTIFIERS Australia

ABSTRACT

This narrative analysis presents one teacher educator's self-study of her first year in teacher education. It occurred when she was the junior partner in redesigning and teaching a science discipline subject to preservice elementary educators. The three-part learning and teaching model they developed included cooperative groups, learners' questions, and a technoscience context. Study data came from preparatory session notes, students' journals, the educator's written questions to students after reading the journals, her journal, audiotaped conversations with students and sessions with the collaborating planner, and students' class notes and projects. Students' expectations of pedagogy and assessment practice collided sharply with the context that was designed. Throughout this paper's discussion of the emergent analytic themes of anxiety, roles, and power, the educator has interwoven reflection on parts of her life history to advance the understanding of her practice. Some of this study's significance lies in its implications for extending the methodology of self-study. By including in self-study of practice analysis of a colleague's philosophy of learning and teaching, one can uncover and better understand one's own philosophy. Another significant aspect of this research lies in its method of analyzing self-study. The teacher educator suggests that selecting context, not the individual, as the unit of analysis in self-study of practice within a Vygotskian theoretical framework leads to a deepened understanding of one's practice and hence of ways to improve pedagogy. (Contains 39 references.) (SM)

**********
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
**********

# Collisions in a science education reform context: Anxieties, roles and power

ED 431 733

SCOPE OF INTEREST NOTICE
The ERIC Facility has assigned this document for processing to: SP
In our judgment, this document is also of interest to the Clearinghouses noted to the right. Indexing should reflect their special points of view. SE

**Dr Gilda Segal**

**Change in Education Research Group**

**Faculty of Education**

**University of Technology, Sydney**

This paper is part of the interactive symposium

**SELF STUDY ON THE ROAD TO REFORM IN TEACHER EDUCATION: OBSTRUCTIONS, DETOURS AND RINGROADS,**

Self-Study of Teacher Education Practices SIG,

Annual Meeting of the American Educational Research Association,

Montreal, Canada, 19-23 April 1999,

21 April 1999, Session 27.21

**Contact details:**

Dr Gilda Segal,

Faculty of Education,

University of Technology, Sydney,

P O Box 222, Lindfield, NSW 2070,

AUSTRALIA.

Email: gilda.segal@uts.edu.au

http://www.education.uts.edu.au/projects/cerg

Other participants in the symposium are:

Professor Christine E. Deer,

Dr Sandy Schuck,

Dr Kim Walker.

SP038594

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY

G. Segal

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)





BEST COPY AVAILABLE

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

# Collisions in a science education reform context: Anxieties, roles and power

**Gilda Segal**

**University of Technology, Sydney**

## ABSTRACT

This paper is a narrative analysis of my self-study of practice as a teacher educator in my first year in teacher education. My self-study took place in the somewhat unusual circumstances of being the junior partner in redesigning and teaching a science discipline subject to alienated elementary teacher education students. Students' expectations of pedagogy and assessment practice collided sharply with the context we had designed. Throughout my discussion of emergent analytic themes of anxiety, roles and power, I have interwoven reflection on parts of my life-history to advance my understanding of my practice. One aspect of the significance of this study lies in its implications for extending the methodology of self-study. By including in self-study of practice analysis of a colleague's philosophy of learning and teaching, one can uncover and better understand one's own philosophy. Another aspect of significance of this research lies in its method of analysis of self-study. I suggest that selecting context, not the individual as a unit of analysis in self-study of practice within a Vygotskian theoretical framework leads to deepening understanding of one's practice and hence of ways to improve pedagogy.

## INTRODUCTION

### Background

Evidence steadily accumulated in Australia in the early nineties to support the findings of the *Discipline Review of Teacher Education in Mathematics and Science* (Speedy, Annice, & Fensham, 1989) that practising and student elementary teachers have negative attitudes towards science and display a reluctance to teach it, especially in the physical science and technological areas (e.g. Cobbin et al., 1989). Possible reasons for these attitudes include lack of discipline knowledge (Ginns & Watters, 1995; Skamp, 1989), lack of confidence due to poor discipline knowledge (Appleton, 1991) and dislike of secondary science (Appleton, 1992). The Discipline Review also highlighted that nothing much was being done to redress this state of affairs.

One of the recommendations of the Discipline Review was that teacher educators include science discipline knowledge in teacher education courses. How to undertake that task, without further reminding student elementary teachers of their dislike of learning science represented then, and still does represent, a significant challenge for elementary science teacher education (Fensham, 1998). One way the challenge to teacher educators was accepted at the University of Technology, Sydney was to re-design an elementary teacher education elective subject, *Science and Technology in Australia*. This was a background science discipline subject that could be elected by final-year students who had not taken a science major elective stream. However most of the students who

were enrolled in *Science and Technology in Australia* did not elect to study it; they were unable to gain their first choices of background elective and for staffing reasons were placed into this subject.

A senior colleague whom I shall call Neil invited me to participate in researching and teaching *Science and Technology in Australia* using a learning model that was novel for the students, but that he hoped would rekindle their interest in learning science. He asked me to suggest ways in which my interest in gender and physical science could be integrated into his existing pedagogical plans for the students (a mainly female group) to undertake an investigation using a learners' questions approach (Faire & Cosgrove, 1988), within a technoscience context (refrigeration or robotics). To assist students to succeed in conditions that would be new to them, I suggested that they work in cooperative groups (Johnson, Johnson, & Holubec, 1990) so that they could support each other socially, emotionally and cognitively, an acknowledged strength of cooperative groups (Brown & Palincsar, 1989).

Thus we designed our three-part learning and teaching model (cooperative groups, learners' questions and a technoscience context) to be gender inclusive. Prior research (Cosgrove, Newman, & Forret, 1987) indicated that the refrigeration context used with a learners' questions approach became very interesting for female secondary students. The learners' questions approach, based upon Biddulph and Osborne's (1984) interactive teaching approach and Barnes' (1976) conversational discourse is an alternative way of teaching that offers autonomy in learning about areas of interest to students.

We were aware that the students, whose interests in general lay in discipline areas other than science, would be challenged in the new *Science and Technology in Australia*. The considerable challenge was embedded in the alternative pedagogy of learners' questions and the technoscience context, but not in the cooperative group component of the learning model; students often engaged in group work in their course. However at the time of this research, students had played little, if any part in planning or in negotiating their own learning in teacher education subjects at this University. Even in their final year of their three-year course, such autonomy was not customary (see Deer, 1999; Schuck, 1999). Collision between lecturer plans for a technoscience context embedded in alternative pedagogy and student expectations of traditional teaching was likely!

My experience in discussing with Neil my research on my practice and indeed on the complexities of all participants' learning and teaching within *Science and Technology in Australia* was my initiation into self-study of practice as a teacher educator in my first year in teacher education. That

experience of self-study of practice in the somewhat unusual circumstances of being the junior partner in re-designing and teaching a science discipline subject to alienated elementary teacher education students forms the substance of this paper.

**Self study of practice**

As Barnes (1998) has stated, it may not be assumed that everyone shares the same meaning or purposes for the concept of self-study of practice so I now propose to clarify further my purposes for my research into my practice. Barnes (p. xi) relates that participants in the last session of the first Conference on Self-study of Teacher Education suggested five purposes for self-study:

1. To uncover the real story of what was going on in a course;
2. To exert political power upon those who control the conditions under which teaching takes place;
3. To construct new knowledge (traditional research);
4. To enhance the self-knowledge of participants;
5. To celebrate the achievements of a course.

There are elements of all five purposes in my narrative analysis of both my practice in *Science and Technology in Australia* and my reflection upon my practice. This is not surprising, given that my principal purpose in undertaking my research was to achieve the goal that is actually shared by self-study and reflection practitioners - to achieve a better understanding of the pedagogy (Loughran & Northfield, 1998). As Loughran and Northfield (1998) have argued, self-study of practice and reflection differ but they do share that underlying purpose of achieving a better understanding of pedagogy.

My analysis of *Science and Technology in Australia* is overlain by reflection related to both my experiences within my teaching the subject and to the parts of my life history that relate to that teaching. Like Knowles and Cole (1995), I believe that my life history, my sense of self and my practice are inextricably intertwined in my search for understanding pedagogy. I am, however, cognisant of the critique of Fenstermacher (1994) and others who question the nature of knowledge that is inferred from teachers' stories. I also take note of Fenstermacher's challenge to those who work within the Schön tradition (Schön, 1983; Schön, 1987) of reflection-on and in-action to justify claims of practical knowledge, as do Schuck (1999) and Walker (1999). Fenstermacher claims that the inference that teacher knowledge is based on reflection-in or reflection-on action is fragile.

Furthermore he claims that there is a difference between justifying inferences made by educational researchers about the knowledge of teachers and the justification of what the teacher knows.

In providing a preliminary answer to Fenstermacher's (1994) challenge, Munby and Russell (1995) cite and provide evidence for their construct *authority of experience* in their search for understanding about how teaching is learned and how it can be taught. My self-study of practice has elements of the personal practical knowledge of Connelly and Clandinin (1988) and I too claim the authority of experience to justify some of my inferences. Nevertheless, my story is also grounded in an orthodox qualitative research methodology (after Lincoln & Guba, 1985) that seeks knowledge and understanding of events from the perspectives of a variety of participants.

In the following sections, I describe some of the teaching of the *Science and Technology in Australia*, but my description is of course partial and cannot capture the complexities of 10 three-hour weekly sessions. I therefore narrow my focus and confine my tale of self-study to the first few weeks of my experiences within the refrigeration context. I relate that story as I lived it and include some of my feelings that I believe stem from my life history. However, I also interweave into my story my understanding of Neil's thinking throughout this period, as his thinking increasingly served as a foil that sharpened my own understandings of events. Indeed, we spent a few hours each week discussing our planning for the sessions and discussing what we had learned after each session. Students' journals and conversations with students (N = 20, 16 female) allow me to include their feelings and interactions that helped to enrich my understanding of my practice as well.

In the final section of the paper, I summarise my understanding of the efficacy of the methodology that emerged during my self-study of practice. I also suggest that using a Vygotskian theoretical framework that supports the choice of context, rather than an individual, as the unit of analysis is a fruitful path for those who wish to analyse their findings in self-study contexts. First though, I very briefly indicate how my self-study of practice research methodology emerged from the orthodox research methodology with which I began this study.

## RESEARCH METHODOLOGY

My conventional research methodology has its origins in Lincoln and Guba's (1985) naturalistic enquiry paradigm and Erickson's interpretive framework. Data sources include preparatory session notes written after discussion with Neil before each of the class sessions, students' journals, my written questions to students after reading the journals and their replies, my journal including field

notes and my comments and feelings about events, audio-taped conversations with students, audio-taped sessions of Neil interacting with the class and with small groups, audio-taped analytical sessions with Neil and another researcher (up to two hours) after each class session and students' class notes, videos, and projects.

My self-study of practice research methodology, I believe, is somewhat unusual. Because Neil and I collaborated so intensively throughout this research, I found I was gaining insights into his philosophy of learning and teaching as the students' reactions to the learning model forced us to think about the efficacy of that model for them. These insights directly challenged me to think carefully about my own assumptions of practice in teacher education. Thus the additional layer of reflective analysis here that integrates with ways I previously analysed *Science and Technology in Australia* (Segal, 1996; Segal & Cosgrove, 1992, 1993) allows me to view my research through my perception of contrasts between Neil's philosophy of teaching and learning, those of some of the students in the group, and my own.

## SCIENCE AND TECHNOLOGY IN AUSTRALIA: A NARRATIVE OF EVENTS

In telling and analysing the story of my practice in *Science and Technology in Australia*, I will move backwards and forwards across the teaching and learning in its early sessions to discuss the intersection of three analytic themes that emerged – *anxiety, roles and power*. During this discussion, I also reflect on the intersection of my life history and my understanding of my practice as mirrored through my perception of Neil's practice.

### The teaching story

The nature of the collaboration between Neil and myself is a part of this story that has a great bearing upon the unfolding of events. As a more experienced teacher educator and with his knowledge born of experience of the refrigeration context and learners' questions approach, Neil initially took full responsibility for planning the development of student learning through learners' questions within both technoscience contexts (refrigeration and robotics) that he devised. He also ordered all equipment that he needed for activities. It is useful to point out, in view of later events, that he did not explain his plans in detail to me in any of our early discussions and I did not ask for such detail.

As I understood it initially, my teaching responsibilities were to organise the cooperative groups and to develop students' skills in cooperative group membership. My research responsibilities were

to develop understanding of my practice within the boundaries set by our collaboration and to develop understanding of the effectiveness of our three-part learning model of cooperative groups, learners' questions and refrigeration context.

***Session 2***

Session 2 was a critical session for students and for us. Our cautious belief that our Session 1 slow introduction of the learning model was not threatening to students collided with our detection of a wave of anxiety that swept through the group in Session 2. During my analysis of the waxing and waning of that anxiety in Sessions 2 and 3, I discuss my unintentional role in contributing to its effects and the understanding of my practice that developed from that contribution.

When I arrived in time for Session 2, I found our teaching laboratory crammed full of equipment on one side of the room and 27 students crowded on the other side. On the equipment side of the laboratory were: three refrigerators with insulation exposed, freezing coils and condenser accessible; bimetallic strips and heaters; acetone to demonstrate cooling effect on skin; slide set about refrigeration and slide projector; video camera for students' use; digital thermometer; technician to demonstrate making dry ice from cylinder of compressed carbon dioxide.

One third of the class had missed the first three-hour session due to administrative arrangements of which we were unaware. In view of Neil's intention to assist students to assume responsibility gradually for their learning from a beginning that emphasised the relevance of the context to them, this was a significant problem. We therefore needed to change our Session 2 plans to accommodate these late students into the teaching program, a case of reflection-in-action (Schön, 1992) undertaken deliberately, and with great speed .

***My change of role: researcher to teacher when Neil attends to robotics group***

If the influx of late students had not arrived, I would have observed, as a researcher of our learning model, Neil introduce the learners' questions approach; this was a novel approach for me too, as I had only read about it. Instead, I missed his introduction of this approach, as I was involved in introducing cooperative learning to the late students. When I had completed the cooperative learning introduction, Neil invited the late students to join either refrigeration or robotics. He asked me to look after the refrigeration group while he looked after the group that had elected to study robotics.

In my absence, Neil had asked the refrigeration group to write down their prior views about how a refrigerator works, to look closely at the refrigerators on display, to sketch them carefully, and to

list any questions about the refrigerators that occurred to them. I was unprepared for how to continue in this situation and my uncertainty had consequences to which four students refer in journal entries and to which I shall return soon. This was but one incident within the wave of anxiety that swelled around us throughout Sessions 2 and 3. Students did not link the purposes of the activities (e.g. the production of dry ice from a cylinder of compressed carbon dioxide) that Neil had designed to stimulate their scientific inquiry into refrigeration with refrigeration itself. Worse from their point of view was their uncertainty of the meaning and implications for them of Neil's invitation to design their own learning and assessment tasks.

**An anxiety context awaiting students**

Session 2 was designed to stimulate the students to begin their own enquiries. From the passive appearance of four of the six groups of students at the beginning of Session 3 and their unwillingness to approach the refrigerators, it seemed that unease and/or anxiety had persisted during the week between sessions, in spite of my careful attempts to develop their understanding of the supportive nature of cooperative group roles. We seemed to have created a context quite different to the one we had intended. However, even the teacher-directed Session 1 had set some alarm bells ringing.

***Early detection of anxiety***

After Session 1, one of the students, Annette, visited me in my office to enquire about the future direction to be taken in the subject. Annette's visit to me after Session 1 surprised me, as Session 1 was teacher-directed and the group was small, promising at that time a very small student-teacher ratio. Annette was highly concerned that exactly what she had to accomplish for assessment had not been spelled out. She said in relation to her experiences in all subjects:

> Well if they don't give us a direct path as to what to do and it's all airy-fairy and up in the air, I get, as I said, really uptight and tense and worried and I don't know where I'm going, just because I don't know; and I know, that that is because it's the way I've been brought up in the education system and that's even in work and everything, and if someone doesn't directly tell me what I have to do, I mean directly, I'm at a loss. (Annette, prior to Session 2)

I reported this conversation to Neil. It indicates, as Annette herself recognised, that her dependency on direction seemed now to be her preferred learning style, perhaps a legacy of her formal education.

***The learning and teaching model and anxiety***

In our discussion after Session 2 after a busy session trying to accommodate the 11 late students, we pondered on the main sources of the student anxiety that the three of us (another researcher was investigating the robotics context) had detected. Possible factors we mentioned as contributors were: the complex arrangements necessitated by the late arriving students; display of large items of equipment; the prospect of carrying out a scientific investigation; the nature of the assessment (a large amount of student choice), students' low experience of self-directed learning and Neil's philosophy of learning and teaching. Later conversations with students supported our reasoning that all these were contributing factors. Of particular interest to me is the part played by Neil's philosophy of learning and teaching as it was his philosophy that underpinned the subject pedagogy and that initiated my reflection on my own philosophy in relation to his. In the two sections that follow, I reflect upon his philosophy and then upon my contribution to the anxiety of a group of four students.

***Contribution of Neil's philosophy of learning and teaching to initial student anxiety***

Neil believed that his role was to arrange contexts carefully to stimulate autonomous learning, not to lay out a well-defined path for students; hence his philosophy was on a collision course with someone like Annette, who insisted on her preference for order and certainty in whatever learning lay ahead. In our post-Session 2 discussion, Neil articulated alternative approaches that people take to learning.

> My friend ... talks about the fact that some people like to learn by just following their noses; others like to learn by seeing where they are going, by knowing where the target is. [They] ... go straight for it and the chance for a ramble around is put aside, you know. [they have] got to be very clear on where they are going and how they're getting there. Whereas another group, which more accurately again represents the young people who are willing to go on sort of a Pied Piper walk through the forest just to see what's there. Now this sort of methodology is more suitable for that second type of learner than the first sort. (Neil post-Session 2 discussion).

In early discussions with Neil, I was attracted by the sound of the learners' questions part of our learning model and did not fully realise that Neil's philosophy of learning and teaching clashed with my own deep-seated beliefs about learners needing direction for their learning. Although I would not have wished to be Annette, strapped into a secure seat of dependency on a train without having any choice about its destination, I certainly had a preference to be on a track with

possibilities for destinations from which I could select. In spite of my attraction to the philosophy underpinning the learners' questions approach, I was not ready to join Neil philosophically rambling in the woods, without learning tracks in sight for either my own learning direction or for that of my students. Yet our post-session discussions initiated reflection-in-and on-action for Neil as well; the results of his reflection on the pedagogy of the model and the subsequent actions he took to modify the technoscience context have significant implications that feature later in this narration. In effect, he offered students different roads to successful learning and did not abandon them to perish in the crash that produced their anxiety.

***Trying to teach without knowing the ground rules: My contribution to student anxiety***

I have already mentioned that I contributed inadvertently to the anxiety of one group of students. When Neil unexpectedly passed to me the task of taking over the learners' questions part of the learning model he had introduced, one group of two males and two females were gathered around a refrigerator; other groups were seated well away, on the other side of the room. Most students told me they did not need help, but the group around the refrigerator asked me to join them and showed me their diagram of the refrigerator and the many questions they had written about it. The students assumed I was there to answer their questions, but I was faced with two problems. First, I was unsure how Neil wanted me to respond to these expectations; I thought that his intention was that they were to be responsible for finding out answers themselves later. Second, I did not know the answers to some of their questions (for example, "Why is this tubing painted silver, when this one is gold coloured?") and I told them I did not know. Unexpectedly, I found myself in the situation of not knowing the ground rules as Barnes (1998) would describe it.

I tried to guide the students' thinking, but this approach undoubtedly contributed to one student, Emma, feeling that there was insufficient direction about the whole subject and to her probable feelings of "anger, despondency and dwindling enthusiasm." She wrote in her journal:

> The questions we asked a lecturer today on our discoveries were left unanswered and I feel that if a classroom teacher were to behave in the same manner on a regular basis with children they would become angry, despondent and the enthusiasm for the topic would fade. (Emma, Group 2, Session 2, journal)

In addition to Emma's general level of anxiety being increased, another consequence of my actions was that the group assumed that this approach, that they called 'discovery learning', was unsuitable for using with themselves and with children. Deliberately, in Session 3, I tried to undo some damage through holding an extended conversation with this group.

One fortunate outcome of my conversation with them was that it allowed these students to express their feelings about their previous interaction with me in Session 2. In expressing them, they seem to have alleviated (at least partly) the disturbance that interaction occasioned.

> Today I feel that we came a long way in expressing our thoughts and ideas on the teaching methods used so far. In a discussion with Gilda the group discussed similar thoughts on the fact that we didn't necessarily agree with free discovery learning to the point of no direction. It was a great time for us to discuss and let the lecturer know our feelings. (Emma, Session 3, journal)

Some members of this group had expressed their concerns about the subject in journal entries made after Session 1; all were quite agitated after Session 2. Now, after Neil's Session 3 modification that I will shortly describe, after their conversation with me and after advancing their planning, their worries seemed to be behind them. What is more, they seemed to have a clear understanding of the implementation of cooperative learning in terms of group roles and a shared goal, the terms through which I had introduced this approach.

> I personally feel I have achieved a lot today. I now know my role in the group working towards the shared goal - the report. I know what is expected of me and can now begin to research my part. I feel confident our report will be of a high standard. (Rosie, Session 3, journal)

**Reflection on practice and self: roles for inexperienced teacher educators**

Without knowledge of Neil's plans for assisting the students to learn how the refrigerator works, I was thrown into the deep end and had little chance of helping the students effectively; I am glad I had the opportunity to try to make amends in Session 3. Now though, I think I understand better why I did not probe Neil earlier to gain knowledge of his plans and hence, why I was ineffectual in the Session 2 teaching situation. Firstly, I did not fully realise I was inexperienced. To the contrary, I was confident of my ability to teach well after 20 years of secondary teaching. Secondly, I was a little inhibited in questioning my more experienced colleague about his plans and I did not wish to appear ignorant; at that time I did not recognise that such questioning was part of my role as a researcher. Thirdly, I had strong feelings of the need to be independent in my role as researcher.

This theme of dependency/independency has been part of my long-term thinking about how I conduct my life. Similar to the experiences of learning at secondary school described by the student teachers in my interactions with them, my experiences of teaching and learning at school were highly prescriptive and learning by rote led to high success in examinations. My home environment was protective; at that time it was not common to move away from home until marriage. Professionally, I recall instances of lack of initiative in solving practical problems. For example, when I first started to teach, the electric jug in the science staff room stopped working. It simply did not occur to me (a physics graduate!) that I might be able to fix it, to the amazement of one of my male colleagues who fixed it immediately. Becoming more conscious of my tendency to depend upon others to solve minor problems, I now actively resist this way of being and seek ways of taking the initiative in my personal and professional life.

Now I see that, conscious of factors in my life that led to lack of initiative in areas such as problem solving, I was highly attracted to the philosophy of the learners' questions component of the learning and teaching model that Neil had devised. Without experience of autonomy in learning in primary, secondary or even in tertiary education, I was most desirous that prospective primary teachers have these experiences to break this cycle of dependency on others for what to learn and how to learn it. However the best of plans laid for others are not always perceived by those others in favourable light.

**Study of pedagogy in progress: Lecturers and students modify context**

As I have mentioned already, the unease of the students, expressed through their attempted clarification of Neil's expectations for assessment was of concern to him; he recognised in our post-Session 2 discussion that the learning model carried risks for both students and lecturers.

> So what I'm saying, are sort of reflections from the point of view of while you are going through a change, the teacher can feel this, even an experienced one, this sort of attitude, you feel quite fragile - the students are certainly feeling anxious. (Neil post-Session 2 discussion)

Neil's plan for the unit, focussing on the everyday technology of refrigeration to prompt inquiry into scientific principles, with incidental investigations of matters of social and/or historical concerns, seemed alien and non motivating to most students. In Session 3, after observing the students' continued avoidance of the scientific investigations on offer, he carefully pointed out other possible routes so that they could concentrate on alternative focuses for their projects: an historical study of

refrigeration, impact of sociological studies, including questionnaires to people of different ages and cultures about refrigeration. Once students understood the extension of choices available to them, their demeanour changed.

***Students can be autonomous learners as long as they too understand the ground rules***

Student activity became more purposeful in later sessions; individuals prepared during the week so that groups used class time effectively. With the implicit requirement for groups to examine the refrigerators and to use the equipment removed, it became obvious that student groups were quite capable of directing their own learning when motivated to do so, and when assessment requirements were adequately described. It was also clear from conversations and journal entries that they liked the opportunities provided by this research to convey their feelings about their experiences in this subject to their lecturers.

Influenced in initial discussion by Neil's perceptions of the students as lacking the ability to be autonomous learners and as being non-risk takers in their learning, I later revised my opinion. An alternative reading of the students' apparent passivity in the face of a scientific and technological context of challenge became possible. A collision could have occurred, but *both* students and lecturer steered carefully and avoided it. Both had access to power, but the way they exercised their power differed due to difference in positional authority.

**Anxiety and power**

In my early analysis of Neil's decision to moderate his emphasis on the technological aspects of the learning model context in our post-session discussions, I attributed all agency to Neil. In our discussions, we portrayed students as helpless and passive, unwilling to take risks to involve themselves in an unfamiliar context and/or mode of learning. I assumed all power to influence events lay with the lecturers. A closer look shows the analysis to be too simple and perhaps too typical of analyses criticised by Walkerdine (1989) and Davies (1993) that assume that females do not have power to influence events.

A different reading could show that many of the students who were to become social science, rather than science investigators were exercising their student power of resistance very effectively; they forced Neil to recognise the unsuitability of his plans for them and to change his plans for conducting the subject. They did not accept the refrigeration context as one that interested them technologically or scientifically and refused to have anything to do with it, communicating their resistance through passivity. This was an action that carried great risks for them in the final

semester of their course, yet they continued their passive resistance into Session 3. It is probably reasonable to assume that both analytical readings were dynamically interactive and contributed to Neil's decision to modify his planning.

Previously also, Neil and I focussed on individuals when we asked ourselves what caused their anxiety and why they were unwilling to take risks. Such an analysis has the potential to assign blame to individuals who do not respond to opportunities offered for learning. However, if analysis is undertaken using a Vygotskian theoretical perspective, a more useful outcome than assigning individual blame is possible. When a context is taken as the unit of analysis, for example as is advocated by Wertsch, (1991) and McDermott (1993), human action cannot be separated from its social or cultural setting. It is then more difficult to blame individuals for not learning, for not taking risks, for not having a suitable attitude to learning and so on.

My present interpretation of these events now clarifies for me an assumption (that I did not initially recognise) underpinning conclusions in our previous analysis. The conclusions assumed a deficit model in which we were implicitly comparing females to male norms; we concluded that females were lacking a quality - risk-taking in science. We assumed in our previous analysis during our post-session discussions, that risk-taking, a social behaviour that is admired in males, is the standard by which all people should be judged. Asking different questions and choosing different units of analysis that include social context allows an understanding of learning to emerge that does not seek to assign praise or blame to individuals or groups for gender-associated social behaviours.

So far, only half the story of my practice and of my role within the three-part learning model in *Science and Technology in Australia* has been related. A minority of students did choose to enter the technological context that Neil devised and this story of self-study of practice would not be complete without elaborating upon their experiences and upon my role within them as a learning guide. This part of the narrative commences when Neil suddenly suggested before Session 3 that I incorporate the role of physics explainer within my role in the subject.

***My anxiety at the prospect of undertaking a hands-on investigation of the refrigerator***

After Session 2, I discussed the learners' questions approach with Neil in more detail and I then felt more informed about the context of my self-study and comfortable once again in my role as researcher of the pedagogy within this discipline subject. Then Neil discussed his plans for the next session, Session 3.

In view of the student anxiety, he thought that some explicit learning was needed with the refrigeration group, on the refrigerant, the structure of the refrigerator and how it works. He suggested that we should be the physics explainers and (I now assume in reaction to my expression) said he would explain how the refrigerator worked, before the next class. As I wrote in my journal after that conversation:

> I reacted in the most dependent way I can now imagine. What does he envisage? I do not really know what all the bits and pieces are. How ridiculous! Why couldn't I take it upon myself to find out. To get a book and go and compare it to the model. For heavens sake! (*Gilda's journal*, 8/8/91)

Apart from this reaction stemming both from my dismay at needing to work out how the fridge works from an actual fridge and from my inner determination to cast off my dependency on others. Neil's suggestion disturbed me in three ways:

1. I thought about the learning model context more personally, and admitted to myself that I was just as disinterested as many of the students in approaching a refrigerator to find out how it works.
2. I wondered how I could simultaneously carry out that part of my role researching learning within the subject if I could no longer observe Neil as he guided students' learning.
3. I did not understand how our roles as explainers fitted with our roles as guiding students' learning through the learners' questions approach.

Once again, I did not voice my concerns, this time because I perceived Neil to be in charge of the subject and I did not see it as my role to question his decisions about the aspects of the learning model in his domain of experience. I should add here, that Neil similarly gave me complete autonomy in implementing anything to do with cooperative groups.

I did not doubt that I could understand how the refrigerator worked in theory. After all, I am a successful science graduate. While I was a secondary science teacher, I was accustomed to explaining to my students scientific principles of motors and generators, for example, using small models. However, my technical and technological experience is very limited and I had never approached large machines to find out how they worked and nor had I ever wanted to do so.

***Relieving anxiety: Finding out how a refrigerator works***

Motivated by necessity, I revised my knowledge of refrigeration using a text book and went to make sense of the actual refrigerator myself, not wanting to be shown. Almost immediately, I came upon a puzzle. In tracing the path of the refrigerant, I found there was only one entrance and no apparent exit to its path around the evaporator. Text diagrams show an entrance and exit path. I went to Neil and discussed with him how peculiar the construction seemed. He reacted with great delight and I can certainly say I have never felt so pleased with myself in any learning situation. Solving that puzzle is the key to understanding how the refrigerator becomes cold.

In the next session, I guided the learning of two initially reluctant students, Mary and Simone, as they solved the same puzzle. Simone and Mary, although at first disinterested in the refrigeration context, were not typical of the majority of the class, in that they both retained positive feelings about science from their high school experiences.

**Self-study of practice as a learning guide: A drinking duck and a learning guide assist Simone and Mary**

In Session 3, by which time Neil had envisaged that students would be actively engaged in finding ways to answer their own questions about refrigeration and how refrigerators work, Simone and Mary were among the students sitting quietly around the room, apparently doing very little. It was in this session that Neil produced a freon drinking duck. He intended that the duck be a motivating problem that might act as a bridge for students to investigate the refrigerators.

I joined Simone and Mary in considering how the duck worked. After our conversation about the drinking duck, I suggested that we go across and look at the refrigerators, but they demurred. (In this reaction they were typical of other groups. As one student said to me: "We can look at our refrigerators at home!") Thinking about how I might involve them in beginning their investigation, I made an alternative suggestion that we look at a slide set about how refrigerators work (which was available for student use, but which thus far had been ignored). Following this relatively passive activity of looking at slides and reading the commentary, they adopted my suggestion of trying to match up the identification of the parts of the real refrigerator with the diagrammatic representations of the slide set.

Moving across from the slide set to the refrigerator, we tried to identify the components named in the slide set. This was not straightforward, as the slide set diagrams of refrigerator components were schematic and did not match their positioning in the refrigerator we were examining, the same

situation as I had found with my text book comparison. Furthermore the evaporator and condenser were represented identically in the slide diagrams.

Then, gradually, as they tried to trace the circulation of the refrigerant, by identifying the hot and cold parts, they vigorously asked questions, made exploratory statements and offered tentative explanations. Their discourse was very insightful, culminating with Mary's question "How does it get so cold again after being so hot?" This is the cognitive essence of the learners' questions component of the model: to provide the conditions in which students can formulate questions, which, when answered, provide powerful insights. And what is more, Mary asked the most crucial question of all: "How does it get so cold again after being so hot?"

Mary and Simone continued to try to trace the refrigerant path. In the slide set diagram as in my text book, this was easy, as the diagram showed the path to be continuous. In the actual refrigerator, some cunning engineering altered the appearance of this continuity. Simone suggested the solution to this puzzle, "It must come in the one tube, go up and down in the one tube."

The three of us were delighted with the outcome of their investigation, an exhilarating experience. Not only did they find that the coldest part occurred where the evaporator tube became very narrow, but Mary linked this to the formation of dry ice in the demonstration of the week before, ("like that stuff over there did"). Temperature measurements resolved the puzzle of the refrigerant seemingly entering and leaving the evaporator by the same tube, by making clear not only the direction of the refrigerant through the evaporator, but also by confirming that there must be two concentric tubes for entry and exit.

**Reflection on roles in learning with Mary and Simone**

During the extended time that it took to fathom out the path of the refrigerant, Simone, Mary and I put forward our ideas as equals. The equality came about because I was puzzled too, when we tried to match up the stylised diagrams of the slide set with the real refrigerator, in spite of my extensive preparation between Sessions 2 and 3 for my role as a learning guide. I did not realise until I was a full participant in their explorations that my own understanding was tenuous and drifted in and out of my head into the collaborative inquiry context that emerged. In genuinely seeking to understand how they were learning, I was involved in the appropriation process myself.

Thus for me, appropriation – the Vygotskian term for collaborative understanding becoming individual understanding (Rogoff, 1990) has an emotional component that also became part of our collaboration in learning. On reflection, I think that the personal satisfaction that I had experienced

prior to my interaction with Simone and Mary may have unconsciously influenced my actions with them. After a positive boost to my confidence, I was probably keen that students should experience this type of inner satisfaction through the learners' questions part of the learning model.

***My role as a learning guide***

From Rogoff's (1990) theoretical framework of guided participation, my role was to guide Simone and Mary into a pre-determined scientific and technological culture through meaningful problem solving. From this theoretical perspective, teachers and learners together solve problems that are meaningful to both, in learners' zones of proximal development. According to Vygotsky (1978)

> [The zone of proximal development] is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (p. 86)

In models of learning and teaching based upon the concept of the zone of proximal development, (e.g. Forman & Cazden, 1985; Palincsar, 1986), the role of teachers or more experienced peers as modellers of ways of learning and of solving problems is central. Early in the learning, teachers assume more responsibility for the problem solving as illustrated by my taking responsibility for gradually encouraging Mary and Simone to tackle the problem of how a refrigerator works. As Mary and Simone become more confident and knowledgeable, I surrendered this responsibility ( a forced surrender in my case as I too grappled to understand the problem) and Mary and Simone become autonomous and successful problem solvers.

***Inferences about best practice for role as learning guide***

My two experiences as a learning guide, juxtaposed, are interesting to consider. First, with the group of four students although I was uncertain of Neil's expectations, I was not a novice teacher. I was confident that I could, through questioning students about their views, help them to think more deeply about those views, without answering their direct questions. I was positioned by the students as the expert, but did not enact that role. Sadly, neither my expectations for effective teaching by guiding, nor those of the students for learning through being told, were met.

On the other hand, my interaction with Simone and Mary at the beginning was much more leisurely, facilitated by their interest in the freon duck and the relatively non threatening slide set. We had established common knowledge, as Edwards and Mercer (1987) define this concept, in terms of developing shared understanding of content, perspectives and our personalities, *before* the

difficult task of conversing about the actual refrigerator began. Hence, Simone and Mary themselves were able to determine the time where they took over responsibility for appropriating technoscience concepts within the thermodynamic context. The contrast between these two ways of interacting with learning partners, the first, too quickly within an expert/novice framework, and the second, slowly, with time for students to assume real responsibility for learning, was underlined by an interaction that Simone and Mary had with another student.

***Differentiating guiding learning from teacher-telling in small groups***

Another student, whose own appropriation of technoscience concepts had been facilitated by Neil in Session 3, offered to assist Simone when she and Mary decided in Session 4 that they also wanted to find out how the thermostat worked. The student was well meaning and began to assist Simone and Mary in the presence of Neil.

The student, as teacher, assumed full responsibility for Simone's learning, and carefully explained and demonstrated to her how the thermostat worked. He then proceeded to quiz her on her understanding, to her great embarrassment. Simone later explained to me what had happened, using an analogy:

> It's like saying to Mary, you know, I went out on Saturday night and I left at 6.30 and I got to the place at 7 o'clock and I drove the car and it was my car and I went to this place and then I changed and went to this place and so and so and so and so and then I said to Mary: So, what time did I leave? and What car was I driving? (Simone, Session 4)

In reflecting on my view now of the role of learning guide as part of my self-study of practice, I realise that a learning guide is an essential feature of this learning model, but the learning guide role is a sensitive one. Its essence lies in the joint context established by teaching that is sensitive to learners' feelings and that avoids the evaluative trilogy of teacher explanation, inquisition of student understanding and evaluative comment (Lemke, 1990; Mehan, 1979). A significant challenge for me now is how to be that sensitive guide, leading learners slowly into a context that they do not want to enter, when there are many students and only one lecturer.

## DISCUSSION OF ISSUES ARISING FROM SELF-STUDY OF PRACTICE

In looking back upon my research into my practice in *Science and Technology in Australia*, I have found it useful to analyse my experiences of teaching within a Vygotskian theoretical framework. I have made the assumption that it is fruitful to analyse my practice as a learning guide in terms of

interactions within my context, rather than by simply analysing my own actions and reflecting upon those actions as though they could be isolated from their context. Thus my analysis implies understanding relationships and interactions between participants (Neil, the students and myself), the learning and teaching model and the physical surroundings. I therefore ask myself, what have I learned through my interactions within this context of which I am a part. What have I learned as a learning guide in interacting with students? How did Neil's learning model contribute to this learning? What have I learned about my philosophy of learning and teaching through interacting with Neil?

**The pervading influence of Neil's philosophy of learning on my thinking: Self-study of practice through interactions with students**

It was Neil'vision for the pedagogy in *Science and Technology in Australia* that has thrown into relief my understanding of my practice. For those whose interests lie in improving science education, understanding useful entry points is essential. Without entry, successful forays of any kind, social or scientific, cannot proceed. If there is a choice of entry and students do not take it, students exclude themselves from significant aspects of their cultural heritage. The question is genuinely problematic for the future of science education, given existing evidence that 13- to 15-year-old students in Western Australia elected to study less science and made explicitly sex-stereotypical choices of science discipline subjects when science was no longer compulsory (Rennie & Parker, 1993).

As a learning guide, I have become much more sensitive to the nuances of how to entice students to make an initial plunge into contexts they may not find attractive. From my authority of experience that sits within the Vygotskian theoretical framework, it is very important to work carefully within zones of proximal development of *both* students and guides. Firstly, many entry points into contexts that are anticipated not to attract students are required and guides will need to prepare well to ensure that students are not simply confused by such abundance. Much of the equipment that Neil had assembled confused the students and did not attract them, but the freon duck, for Mary and Simone, was the point of entry. For other students, historical and sociological studies of the context provided points of entry.

Secondly, once students took their first tentative steps towards a context that held no initial attraction for them, I learned how slowly I should advance. Judging pace within each other's zones of proximal development is important, again for both learners and guides. Mary and Simone refused to come over the actual refrigerators at first, but they did agree to look at the slides. I

learned not to rush the students and to allow them gradually to deepen their interest in their context and their trust in the nature of our interaction. Thirdly, a view of the nature of learning that does not equate learning with having a knowledge bank is useful to establish trust. I understood that quizzing Mary and Simone about their understanding would have been counterproductive – a denial of trust in their ability to learn. Related to the establishment of trust is the nature of challenge in the learning context. In more familiar contexts of looking up library books to undertake less practical research, I found I was not needed and I therefore did not establish the same level of communication and trust with the social science investigators as with Mary and Simone.

Fourthly, in unfamiliar or alien contexts such as a technoscience one that appears to offer too great a challenge, it is not realistic to expect autonomy of learning too soon. Under these circumstances, a cooperative friendship group is a useful supportive structure. The learning model and my interactions with Simone and Mary created conditions for learning where they began to overcome their assumptions of dependence on me to tell them what to learn and how to learn it. Mary and Simone were close friends and their support for each other's learning made this transition into autonomy of learning less daunting.

I learned too from my initial unsuccessful interactions as a learning guide. These interactions highlighted for me the importance of what I already knew: it is essential for any teacher to have an excellent subject matter knowledge and pedagogical content knowledge (Shulman, 1986; Shulman, 1987). In this early interaction, I could bring neither to bear.

**The pervading influence of Neil's philosophy of learning on my thinking: Self-study of my philosophy of learning and teaching**

Through interacting with Neil, I had the opportunity to be part of a double context within which his assumptions about learning and teaching were operating: his philosophy of learning and teaching underpinned his pedagogy with the students but, I realise more clearly now than I did at the time, it was also guiding his interactions with me, a neophyte teacher educator and researcher. Neil offered both the students and me choices in epistemology and methodology. We were able to question our view of the nature of knowledge and how to learn. Neil showed us that the way to learn was to ask questions about what was of interest to us. The deeper our questions became, the more we would learn and in turn, the more interested we would become. His philosophy clashed with our previous assumptions – mine and the students' as I now recognise. Some of the students could not accept initially the freedom to learn that Neil offered them. Never having experienced such choice, they were inhibited by it. Wisely, I believe, Neil decided to alter the boundary conditions and made it

learned not to rush the students and to allow them gradually to deepen their interest in their context and their trust in the nature of our interaction. Thirdly, a view of the nature of learning that does not equate learning with having a knowledge bank is useful to establish trust. I understood that quizzing Mary and Simone about their understanding would have been counterproductive – a denial of trust in their ability to learn. Related to the establishment of trust is the nature of challenge in the learning context. In more familiar contexts of looking up library books to undertake less practical research, I found I was not needed and I therefore did not establish the same level of communication and trust with the social science investigators as with Mary and Simone.

Fourthly, in unfamiliar or alien contexts such as a technoscience one that appears to offer too great a challenge, it is not realistic to expect autonomy of learning too soon. Under these circumstances, a cooperative friendship group is a useful supportive structure. The learning model and my interactions with Simone and Mary created conditions for learning where they began to overcome their assumptions of dependence on me to tell them what to learn and how to learn it. Mary and Simone were close friends and their support for each other's learning made this transition into autonomy of learning less daunting.

I learned too from my initial unsuccessful interactions as a learning guide. These interactions highlighted for me the importance of what I already knew: it is essential for any teacher to have an excellent subject matter knowledge and pedagogical content knowledge (Shulman, 1986; Shulman, 1987). In this early interaction, I could bring neither to bear.

**The pervading influence of Neil's philosophy of learning on my thinking: Self-study of my philosophy of learning and teaching**

Through interacting with Neil, I had the opportunity to be part of a double context within which his assumptions about learning and teaching were operating: his philosophy of learning and teaching underpinned his pedagogy with the students but, I realise more clearly now than I did at the time, it was also guiding his interactions with me, a neophyte teacher educator and researcher. Neil offered both the students and me choices in epistemology and methodology. We were able to question our view of the nature of knowledge and how to learn. Neil showed us that the way to learn was to ask questions about what was of interest to us. The deeper our questions became, the more we would learn and in turn, the more interested we would become. His philosophy clashed with our previous assumptions – mine and the students' as I now recognise. Some of the students could not accept

initially the freedom to learn that Neil offered them. Never having experienced such choice, they were inhibited by it. Wisely, I believe, Neil decided to alter the boundary conditions and made it possible for everyone to learn about refrigeration, although not necessarily its science and technology.

I too was inhibited in my interactions with Neil, but in a different way to the students. Because of my perception of a power imbalance in our collaboration due to his seniority and knowledge, I did not ask early questions about his pedagogy or later questions about our interactions. Here, at the time, I was also conscious of stepping over an invisible line and intruding into his personal space. I did not ask whether he was deliberate in his use of the same approaches to learning with me as he did with the students, but I think his actions were deliberate. I now believe I understand why he did not volunteer this information. Consistent with his philosophy of learning and teaching, my belief is that he assumed I was not ready to have those conversations as I did not initiate them. Had I asked, I believe I would have learned even more his philosophy of learning and teaching and hence, I would have deepened my understanding of its contrasts with my own.

## Implications for self-study of practice

### *Addition to methodology*

It is not possible to contact Neil now to ask him about my conjecturing above and nor in one sense is it important that I do so. My authority of experience in these interactions that is set within Vygotskian theorising allows me to draw an important implication for the future development of self-study of practice. Although most of those who engage in self-study do so collaboratively, my collaboration with Neil highlights a new and effective way of engaging in self-study. My finding is that if collaborators study each other's practice with a view to uncovering each other's assumptions about teaching and learning, they will gain access to their own tacit beliefs. With access to hidden assumptions that drive our actions, we can decide whether we want to change and, by making our actions transparent to our students, we can offer them a choice of change of learning style too.

### *Improvement of pedagogy*

Finally, it is pertinent to conclude this self-study of practice with a more general statement on the contribution this study has made to improving pedagogy. In *Science and Technology in Australia*, the success of science investigators and the different success experienced by social science investigators emphasise the importance of finding a number of ways to establish relationships

between learners and their contexts of learning in a variety of learning environments. The pleasure that all investigators gained through planning their own learning outcomes eventually expurgated remnants of anxiety and re-emphasised connections between cognition, affect, and lecturers' and students' personal philosophies of learning and ways of being themselves.

Since working with Neil, I have tried many variations on that three-part learning model: sometimes I have used cooperative learning, sometimes I have used a modification of learners' questions and I have searched for contexts that will appeal to future elementary teachers who are alienated from science. Lately, I have been trying to design learning and teaching models that offer even more varied support to students to assist them develop autonomy of learning within science contexts (Segal, 1999, January). The road is not clear of future collisions. Whichever road I have taken and however many paths of learning I have tried to make available to my students, I have found that it is not possible for some students to avoid collisions within contexts of science education reform. It is still worth trying to assist them to learn science within their zones of proximal development.

**References**


Appleton, K. (1991). Mature age students: how are they different? *Research in Science Education, 21*, 1-9.

Appleton, K. (1992). Discipline knowledge and confidence to teach science: Self perceptions of primary teacher education students. *Research in Science Education, 22*, 11-19.

Barnes, D. (1976). *From communication to curriculum*. Hammondsworth: Penguin.

Barnes, D. (1998). Foreward: Looking forward: The concluding remarks at the Castle Conference. In M. L. Hamilton & S. Pinnegar (Eds.), *Reconceptualizing teaching practice: Self-study in teacher education* (pp. ix-xiv). London: Falmer Press.

Biddulph, F., & Osborne, R. (Eds.). (1984). *Making sense of our world: An interactive teaching approach*. Hamilton, N.Z.: S.E.R.U. University of Waikato-Hamilton Teachers College.

Brown, A. L., & Palincsar, A. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. Resnick (Ed.), *Knowing, learning and instruction: essays in honor of Robert Glaser* (pp. 393-451). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cobbin, A., Bingle, K., Brown, G., Greenaway, V., Hughes, R., & Willis, A. (1989). *Investigating: Science K-6. Evaluation* : NSW Department of Education.

Connelly, F. M., & Clandinin, D. J. (1988). *Teachers as curriculum planners*. New York: Teachers College Press.

Cosgrove, M., Newman, B., & Forret, M. (Eds.). (1987). *Teaching technology - Refrigeration, an example from New Zealand's economic history*. (Vol. 2). Kiel: Institute for Science Education.

Davies, B. (1993). *Shards of glass*. Sydney: Allen & Unwin.

Deer, C. E. (1999, April). *Leading reform in teacher education: A rocky road*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

Edwards, D., & Mercer, N. (1987). *Common knowledge: The development of understanding in the classroom*. London: Routledge.

Faire, J., & Cosgrove, M. (1988). *Teaching primary science*. Hamilton: Waikato Education Centre.

Fensham, P. (1998). *Primary science and technology in Australia: A discussion paper and comparative perspective*. Perth: National Key Centre for School Science and Mathematics at Curtin University of Technology.

Fenstermacher, G. (1994). The knower and the known: The nature of the knowledge in research on teaching. *Review of Research in Education, 20*, 3-56.

Ginns, I. S., & Watters, J. J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. *Journal of Research in Science Teaching, 32*(2), 205-222.

Johnson, D. W., Johnson, R. T., & Holubec, E. J. (1990). *Circles of learning: Cooperation in the Classroom*. (3rd ed.). Edina, MN: Interaction Book Company.

Knowles, J., G., & Cole, A. (1995). Methods and issues in a life history approach to self-study. In T. Russell & F. Korthagen (Eds.), *Teachers who teach teachers: Reflections on teacher education* (pp. 130-151). London: Falmer Press.

Lemke, J. (1990). *Talking science: Language, learning and values*. Norwood, NJ: Ablex.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park: Sage Publications.

Loughran, J. J., & Northfield, J. R. (1998). The nature of knowledge development in self-study practice. In M. L. Hamilton (Ed.), *Reconceptualising teaching practice: Self-study in teacher education* (pp. 7-18). London: Falmer Press.

McDermott, R. P. (1993). The acquisition of a child by a learning disability. In S. Chaiklin & J. Lave (Eds.), *Learning in doing: social, cognitive, and computational perspectives* (pp. 269-305). New York: Cambridge University Press.

Mehan, H. (1979). *Learning lessons*. Cambridge, MA: Harvard University Press.

Munby, H., & Russell, T. (1995). Towards rigour with relevance: How can teachers and teacher educators claim to know? In T. Russell & F. Korthagen (Eds.), *Teachers who teach teachers* (pp. 172-184). London: Falmer Press.

Palincsar, A. S. (1986). The role of dialogue in providing scaffolded instruction. *Educational Psychologist, 21*, 73-98.

Rennie, L. J., & Parker, L. H. (1993). Curriculum reform and choice of science: Consequences of balanced and equitable participation and achievement. *Journal of Research in Science Teaching, 30*(9), 1017-1028.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Schön, D. (1983). *The reflective practitioner*. New York: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.

Schön, D. (1992). The theory of inquiry: Dewey's legacy to education. *Curriculum Inquiry, 22*(2), 119-139.

Schuck, S. (1999, April). *Driving a mathematics education reform with unwilling passengers*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

Segal, G. (1996). *Revaluing primary science education: A developmental, gender inclusive perspective*. Unpublished Ph.D., University of Technology, Sydney, Sydney.

Segal, G. (1999, January). *Sharing learning: Linking students and teacher educators through computer-mediated communication and classroom interaction*. Paper presented at the International Conference on New Professionalism in Teaching, Hong Kong.

Segal, G., & Cosgrove, M. (1992). Challenging student teachers' conceptions of primary science and technology education. *Research in Science Education, 22*, 348-357.

Segal, G., & Cosgrove, M. (1993). *Developing an inclusive technoscience learning environment*. Paper presented at the Contributions to the Seventh International GASAT (Gender and Science and Technology) Conference, University of Waterloo, Waterloo, Ontario, Canada.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*, 1-22.

Skamp, K. (1989). General science knowledge and attitudes towards science and science teaching of pre-service primary teachers. Implications for pre-service units. *Research in Science Education, 19*, 257-267.

Speedy, G. W., Annice, C., & Fensham, P. J. (1989). *Discipline review of teacher education in mathematics and science (Vol 1)* . Canberra: Australian Government Publishing Service.